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THE LATE MIDDLE PLEISTOCENE PROGLACIAL LAKE IN THE KELTMENSKY HOLLOW, SEVERNYE UVALY UPLAND

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The Keltmensky Hollow is a buried canyon that crosses the Severnye Uvaly Upland and connects the basins of Vychegda and Kama. According to a number of authors, this is a relic of the erosion network of the Early Pleistocene, when the present upper reaches of the Kama belonged to the Pechora Basin and flowed into the Arctic Ocean. Periodic blocking by glaciers in the Middle Pleistocene led to the reverting of the upper Kama into the Volga basin and the filling of the canyon with a thick (up to 70-80 m) body of sediments of different origin. Now, along the hollow, rivers flow down: North Keltma - to Vychegda, Southern Keltma - to Kama. However, in the Late Pleistocene, according to a number of authors, the waters of glacier-dammed lakes that filled the basins of Vychegda and Pechora flowed through the Keltmensky Hollow and into the Volga basin. It was assumed that the last such event occurred at the maximum of the last glaciation.

To clarify the history of the Keltmensky Hollow, in 2017 we drilled a 45-m core 17843 at 61.16812 ° N, 54.98654º E. The upper 23.5 m of the section, represented by eolian, alluvial and fluvioglacial sands, document the Late Pleistocene history of the valley, which will be the subject of a special publication. In this paper we consider the lower half of the section, the lithologic-stratigraphic structure of which is the following (Fig. 1).

Layer 6, 23.5-26.0 m: dark gray brownish aleuritic clay with inclusions of clasts (small gravel), very tight. According to the grain size analysis, the average particle diameter is in the range 0.004-0.019 mm, the sorting coefficient varies within the range of 0.23-0.53. As a working hypothesis, the layer was interpreted as the moraine of the Vychegda glaciation (MIS 6).

Layer 7, 26.0-27.6 m: gray fine-grained sand - probably fluvioglacial.

Layer 8, 27.6-42.9 m: a silty stratum with thin horizontal stratification. Up to a depth of 35.6 m, a fairly uniform stratum of sandy-clayey silt with rare interlayers of silty clay is observed. At depths of 36.5 and 37.2, interlayers of fine-grained clayey-siltsty sand were encountered. Below (interval 37.7-40.4 m) there is clayey-sandy silt, downward shifting to sandy-clayey silt. The stratum is interpreted as lacustrine sediments.

Layer 9, 41.3-43.2 m: Brownish-gray fine sand with rare gravel up to 1 cm in diameter, with interlayers of brown sandy loam. The grading coefficient is average and varies within the range of 0.31-0.43. The average particle diameter is in the range of 0.073-0.153 mm. Below 43.2 m, the material could not be trapped by the cylindrical sampler, which indirectly indicates the continuation of the sand composition of the deposits (liquefied sand).

Spore-pollen analysis allowed to recognize the following pollen zones and to reconstruct the following types of vegetation (from the bottom up):

1. Interval 42.70-37.63 m. Light coniferous forests with pine dominance, considerable participation of spruce, admixture of birch (mainly shrub), alder and willow. The climate was relatively warm.
2. Interval 37.5-31.5 m. Forest groups retained their predominance, but the role of bog-grass communities rises. Climate cooling is evident.
3. Interval 31.5 - 24.0 m. Development of birch bush tundras. In addition to the bog-tundra formations, xerophytic communities of wormwood *Artemisia* sp., *Chenopodiaceae mastum*, *Ephedra* sp. All this indicates cold and dry climate.

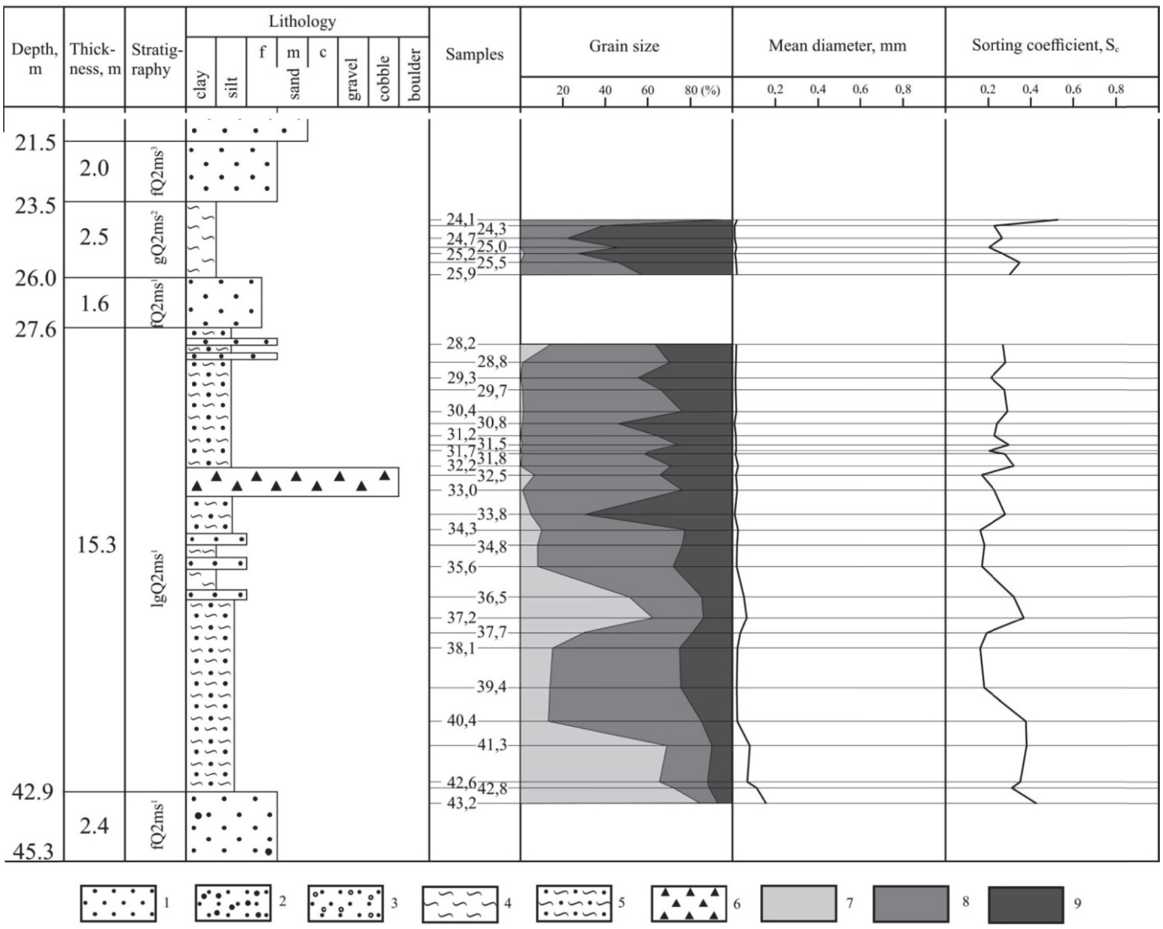

Fig. 1. Lithology of sedimentary filling of the Keltmensky Hollow, core 17843, lower part.
Legend: 1 – sand, 2 – sand with gravel, 3 – sand with cobble, 4 – clay, 5 – loam, 6 – small gravel; grain size fractions 7 –1-0,1, 8 – 0,1-0,01, 9 – <0,01 mm.

On the spore-pollen diagram, a “wave” of warming with the most forested conditions (taiga) in the interval 33-40 m is clearly visible. It was followed by cooling. The upper part (to a depth of 26 m) is already treeless. It is, at best, a forest-tundra. At the same time, drying of the climate occured, which is evident from the growth of wormwood pollen. If the assumption of the glacial origin of layer 6 and its Vychegodskian (MIS 6) age is correct, then the composition and dynamics of the vegetation cover allow us to relate the studied part of the section to the pre-Vychegodskian (pre-Moscovian, MIS 6) interstadial or the ending of the interglacial epoch of MIS 7.

Thus, the available data indicate that in the Keltmensky Hollow the advance of the Vychegda (MIS 6) glacier was preceded by the formation of a proglacial lake. Judging by the great thickness of the sediments, the lake existed for a long time - several thousand years. The high content of sand fractions in the lower half of the section indicates that at first the lake was semi-opened, but later the flow decreased or disappeared at all. Immediately before the arrival of the glacier, a sand layer accumulates - apparently, sediments of glacio-fluvial streams in the vicinity of the ice sheet front that could invade the lake as a delta.

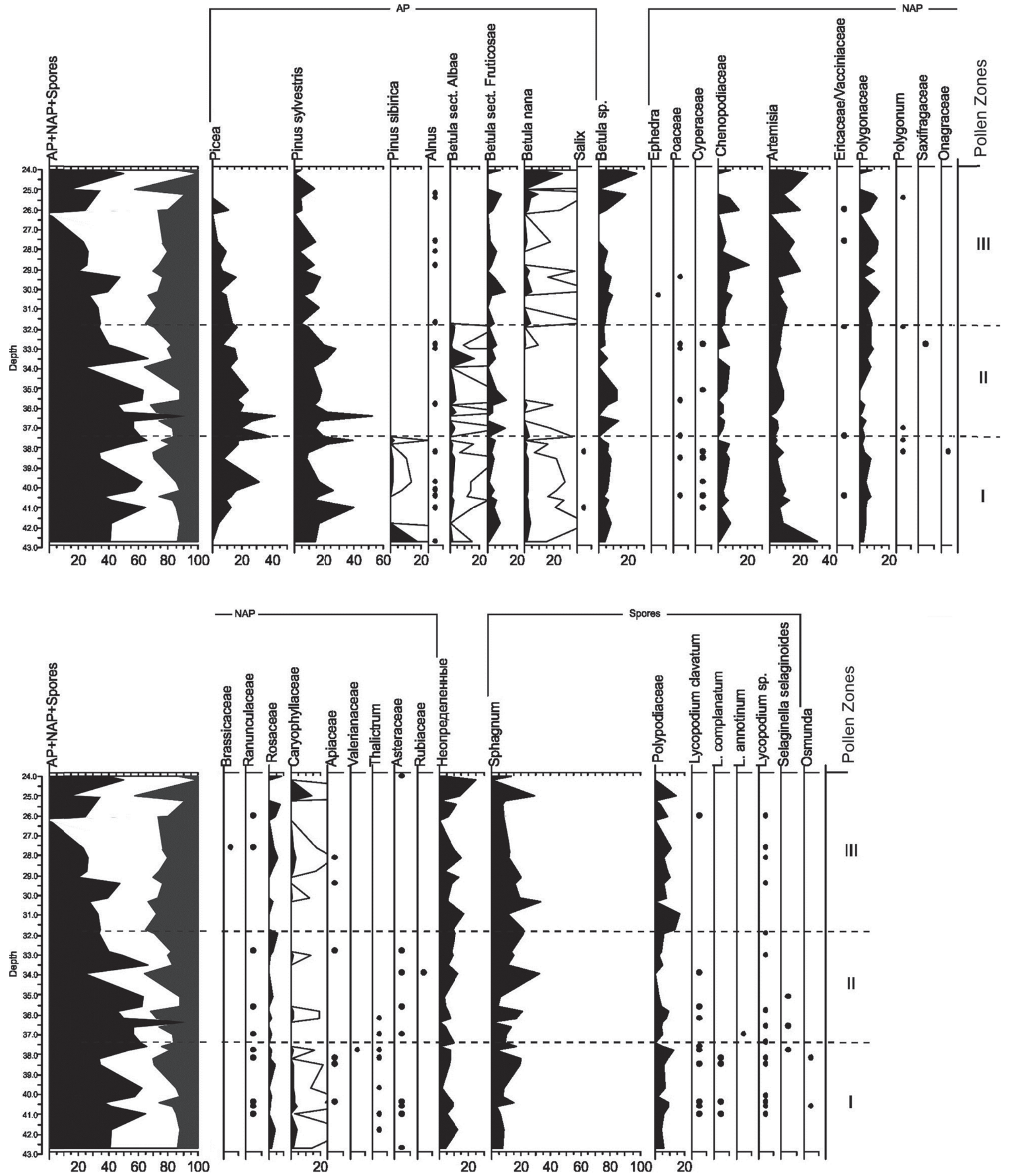

Fig. 2. Pollen diagram of core 17843 (lower part) in Lithology the Keltmensky Hollow

The reason for the formation of the proglacial lake was most likely the subsidence of the earth's crust under the glacier. In the case of the Late Valdai (Scandinavian) ice sheet in the northwest of the Russian Plain, glacioisostatic depression extended 100-200 km beyond the ice sheet and formed a kind of flexure type at the edge of a glacier with an amplitude of just under 100 m. The Vychegodsky (Moscow) glacier was more powerful, and its proglacial flexure could be deeper and wider. The sides of the Keltminsky hollow prevented the outflow of water from the sides, which created favorable conditions for the formation of the lake. Judging by the purely sandy composition of the upper half of the section, immediately after the degradation of the glacier, the lake was not restored, although the crustal rise must have taken place with considerable delay. This indicates that the presence of a glacial dam in the north could be an important factor for the formation of the lake. With its disappearance, the conditions for the formation of the lake basin also disappeared.

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APPLICATION OF FRESHWATER DIATOMS IN THE PALEOLIMOLOGY OF YAKUTIA

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As north Siberia is an area with high present-day warming rates (IPCC, 2013), reliable tools for environmental reconstructions to track lake-system adjustments to climate change on millennial to decadal time scales is of high importance. In addition, the use of environmental indicators that can assess past environments by analysing samples collected from remote sites where continuous monitoring is not feasible would help to decipher recent change. For that purpose, this study aims to set up a regional indicator-diatom set for selected environmental variables for Yakutia. In arctic and subarctic lake waters where low temperatures and ice cover limit other algae, diatoms often substantially contribute to or even dominate the lake primary production (Smol & Douglas, 2007).

Diatoms are sensitive to various environmental variables such as nutrient content and salinity (Anderson, 2000). Diatoms thus have a high potential for indicating change in most environments given that regional diatom–environment relationships are known. Such knowledge is mostly based on diatom assemblages obtained from lake surface-sediments as diatom remains, in contrast to most other algae, are preserved due to their resistant silica valves. While such sub-fossil data-sets already exist for other parts of the Arctic or Eurasia, the distribution of diatom assemblages and their relationship to environmental characteristics in lakes from Siberia in general and Yakutia in particular has not been extensively explored.

Typically, the environmental indication of complete diatom spectra are investigated using multivariate statistical methods, while the indicator value of individual taxa is less often examined (Lotter et al. 1998; Ter Braak & Van Dam, 1989; Wunsam et al., 1995). Gaining such information for Yakutia would be particularly useful to allow a more reliable qualitative and semi-quantitative interpretation of the remarkable number of available fossil diatom spectra (e.g. Pestryakova, 2000; Laing et al., 1999) previously published without the need for taxonomic harmonisation as would be necessary when applying multivariate transfer functions to fossil data.

In particular, this study aims (1) to examine the indicator value of individual species for specific environmental variables and (2) vegetation types (arctic tundra, forest tundra, northern taiga, mountain taiga, typical taiga), and (3) to evaluate the use of such information for both past environmental reconstruction and modern environmental assessments in Yakutia.

The study area comprises the Republic Sakha (Yakutia) situated in eastern Siberia, Russia. The investigated sites are scattered across a large area (56.35-72.83°N; 110.2-161.0°E) covering more than 3,000 km^2. Around 70% of the Yakutian territory is covered by mountains and upland areas. Lowland plains are widespread in the northern and central areas. Modern relief was formed during the Cenozoic. Yakutia is dissected by thousands of rivers (among them the Anabar, Olenek, Vilyuy, Lena, Aldan, Indigirka, and Kolyma) which mostly originate in the various mountainous regions and flow towards the Polar Sea. Yakutia experiences an extreme climate and belongs to three climatic zones: arctic (along the Arctic Ocean shore), subarctic (north of the Vilyuy and northeast of Aldan River),